EECS220 Summary

Chapter 1

- Standardized prefixes – p, n, u,m, k, M
- Definitions of current, voltage, and power
- Ideal basic circuit element
- Reference polarity – passive sign convention

Chapter 2

- Independent and dependent sources
- Ohm's Law
- KCL and KVL

Chapter 3

- Resistors in series and parallel connections
- Voltage and current dividers
- Delta-to-Wye

Chapter 4

- Definitions of essential node, essential path, mesh, planar circuit
- Simultaneous equations, #Eq=#unknown
- Node-voltage method, 2 special cases, supernode concept
- Mesh-current method, supermesh concept
- Source transformation
- Thevenin and Norton equivalent circuits
- Superposition
- Maximum power transfer condition

Node-Voltage Method

- Based on writing KCL equations at essential nodes
- Solves for node voltages
- The “recipe”:
  1. Identify the essential nodes
  2. Pick a reference node
  3. Label remaining essential nodes with voltage values
  4. Write a KCL equation at each non-reference essential node
  5. Put equations in standard form and solve
  6. Check your solutions by balancing power
  7. Calculate quantities of interest

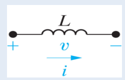
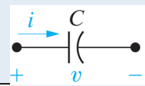
Mesh-Current Method

- Uses KVL equations around meshes
- Solves directly for currents
- Special cases for dependent sources and for current sources in a mesh
- The “recipe”:
  1. Identify the meshes
  2. Label each with a mesh current
  3. Write a KVL equation around each mesh
  4. Put equations in standard form and solve
  5. Check your solutions by balancing power
  6. Calculate quantities of interest

Chapter 5

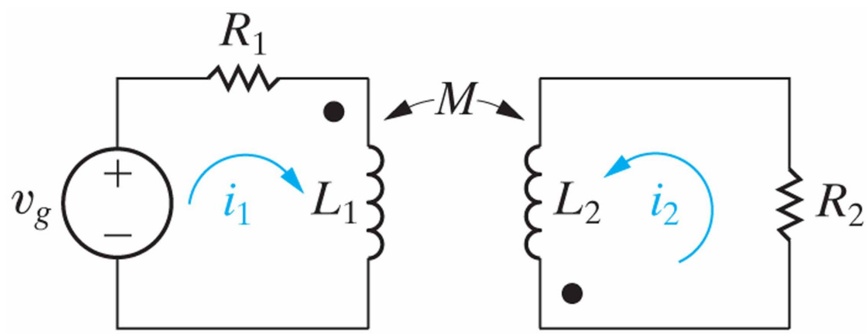
- Definitions of capacitor, inductor(transformer)
- C and L in series and parallel connections
- Definitions of natural and step responses
- Time constants
- Natural responses of RC and RL circuits
- Step responses of RC and RL circuits

Inductor and Capacitor comparison

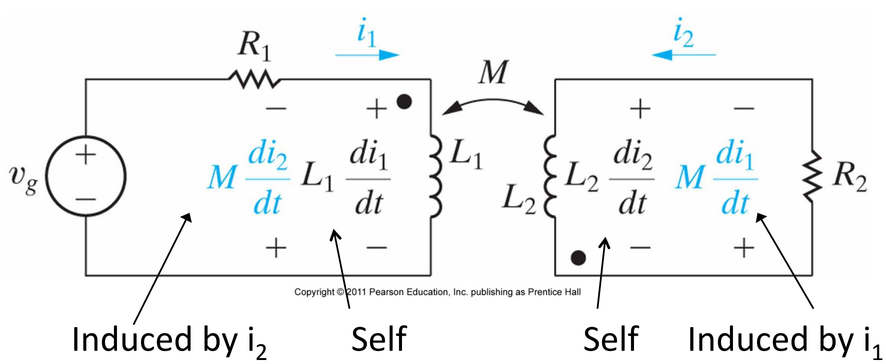
	Inductor	Capacitor
Symbol		
Units	Henries [H]	Farads [F]
Describing equation	$v(t) = L\dfrac{di(t)}{dt}$	$i(t) = C\dfrac{dv(t)}{dt}$
Other equation	$i(t) = \dfrac{1}{L}\int_{t_o}^{t} v(\tau)d\tau + i(t_o)$	$v(t) = \dfrac{1}{C}\int_{t_o}^{t} i(\tau)d\tau + v(t_o)$
Initial condition	$i(t_o)$	$v(t_o)$
Behavior with const. source	If *i(t) = I, v(t) = 0* → short circuit	If *v(t) = V, i(t) = 0* → open circuit
Continuity requirement	*i(t)* is continuous so *v(t)* is finite	*v(t)* is continuous so *i(t)* is finite

Inductor and Capacitor comparison

	Inductor	Capacitor
Power	$p(t) = v(t)i(t) = Li(t)\dfrac{di(t)}{dt}$	$p(t) = v(t)i(t) = Cv(t)\dfrac{dv(t)}{dt}$
Energy	$w(t) = \frac{1}{2}Li(t)^2$	$w(t) = \frac{1}{2}Cv(t)^2$
Initial energy	$w_o(t) = \frac{1}{2}Li(t_o)^2$	$w_o(t) = \frac{1}{2}Cv(t_o)^2$
Trapped energy	$w(\infty) = \frac{1}{2}Li(\infty)^2$	$w(\infty) = \frac{1}{2}Cv(\infty)^2$
Series-connected	$L_{eq} = L_1 + L_2 + L_2$ $i_{eq}(t_o) = i(t_o)$	$\dfrac{1}{C_{eq}} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ $v_{eq}(t_o) = v_1(t_o) + v_2(t_o) + v_3(t_o)$
Parallel-connected	$\dfrac{1}{L_{eq}} = \dfrac{1}{L_1} + \dfrac{1}{L_2} + \dfrac{1}{L_3}$ $i_{eq}(t_o) = i_1(t_o) + i_2(t_o) + i_3(t_o)$	$C_{eq} = C_1 + C_2 + C_2$ $v_{eq}(t_o) = v(t_o)$



Dot Convention: When the reference direction for a current entering (leaving) the dotted terminal in a coil, the reference polarity of the voltage that it induces in the other coil is positive (negative) at its dotted terminal.



$$-v_g + i_1R_1 + L_1\frac{di_1}{dt} - M\frac{di_2}{dt} = 0$$

$$i_2R_2 + L_2\frac{di_2}{dt} - M\frac{di_1}{dt} = 0$$

RL/RC Natural Response

1. Identify the variable of interest (hint – it's the variable that must be continuous in the circuit):
   - For RL, *i(t)* through L
   - For RC, *v(t)* across C
2. Find the initial value of this variable, either $i(0) = I_o$ or $v(0) = V_o$
   - From the problem statement.
   - By analyzing the circuit for $t < 0$, with L replaced by a short circuit or C replaced by an open circuit

RL/RC Natural Response

3. Find the time constant, τ
   - $\tau_{RL} = L/R_{eq}$ or $\tau_{RC} = R_{eq}C$
   - Note that R_{eq} is the equivalent resistance as seen from the inductor or capacitor for $t \geq 0$
4. Write the expression for the variable of interest:

   $$x(t) = X_o e^{-t/\tau}, \quad t \geq 0$$
5. Use simple circuit analysis to calculate any other requested variables.

RL/RC Step (Natural) Response

1. Identify the variable of interest (hint – it's the variable that must be continuous in the circuit):
   - For RL, *i(t)* through L
   - For RC, *v(t)* across C
2. Find the initial value of this variable, either $i(0) = I_o$ or $v(0) = V_o$
   - From the problem statement
   - By analyzing the circuit for $t < 0$, with L replaced by a short circuit or C replaced by an open circuit

RL/RC Step (Natural) Response

3. Find the final value of this variable, either $i(\infty) = I_F$ or $v(\infty) = V_F$
   - If there is no source in the circuit as $t \rightarrow \infty$, the final value is 0 – this is the natural response problem!
   - Otherwise, analyze the circuit as $t \rightarrow \infty$, with L replaced by a short circuit or C replaced by an open circuit
4. Find the time constant, τ
   - $\tau_{RL} = L/R_{eq}$ or $\tau_{RC} = R_{eq}C$
   - Note that R_{eq} is the equivalent resistance as seen from the inductor or capacitor for $t \geq 0$

RL/RC Step (Natural) Response

5. Write the expression for the variable of interest:

$$x(t) = X_F + (X_o - X_F)e^{-t/\tau}, \quad t \geq 0$$

6. Use simple circuit analysis to calculate any other requested variables.

Chapter 6

- Forms of reponse of RLC circuits: underdamped, critically damped, overdamped
- Natural response of parallel RLC circuits
- Natural response of series RLC circuits
- Step response of parallel and series RLC circuits

Natural Response of Parallel & Series RLC Circuits

The solutions are in the same form for parallel and series RLC circuits:

$$v(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t} \qquad \text{Overdamped}$$

$$v(t) = B_1 e^{-\alpha t} \cos \omega_d t + B_2 e^{-\alpha t} \sin \omega_d t \qquad \text{Underdamped}$$

$$v(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t} \qquad \text{Critically damped}$$

$$i(t) = A_1 e^{s_1 t} + A_2 e^{s_2 t} \qquad \text{Overdamped}$$

$$i(t) = B_1 e^{-\alpha t} \cos \omega_d t + B_2 e^{-\alpha t} \sin \omega_d t \qquad \text{Underdamped}$$

$$i(t) = D_1 t e^{-\alpha t} + D_2 e^{-\alpha t} \qquad \text{Critically damped}$$

Series and Parallel RLC Circuits

- The difference(s) between the analysis of series RLC circuit and the parallel RLC circuit is/are:
  A. The variable we calculate.
  B. The describing differential equation.
  C. The equations for satisfying the initial conditions

Step Response of RLC Circuits

- Generally speaking, the solution of a second-order DE with a constant driving force equals the forced response plus the a response function identical to the natural response.

$$i = I_f + \begin{Bmatrix} \text{function of the same form} \\ \text{as natural response} \end{Bmatrix}$$

$$v = V_f + \begin{Bmatrix} \text{function of the same form} \\ \text{as natural response} \end{Bmatrix}$$

- I_f or V_f is the non-zero final value.

Chapter 7

- Phasor transform and inverse phasor transform
- Impedance of R, L, C – R: I & V in-phase, L: I lags V by 90°, C: I leads V by 90°
- Phasor domain representation
- Sinusoid steady-state analysis
- Source transformation
- Thevenin equivalent

Phasor Domain Representation

- In the time domain
  - Ohm's law (only for resistors): $v = Ri$
  - KVL (around a loop): $v_1 + v_2 + \ldots + v_n = 0$
  - KCL (at a node): $i_1 + i_2 + \ldots + i_n = 0$
  - These three laws lead to all other time-domain circuit analysis techniques
- In the phasor domain
  - Ohm's law (for R, L, C): $\boldsymbol{V} = Z\boldsymbol{I}$
  - KVL (around a loop): $\boldsymbol{V}_1 + \boldsymbol{V}_2 + \ldots + \boldsymbol{V}_n = 0$
  - KCL (at a node): $\boldsymbol{I}_1 + \boldsymbol{I}_2 + \ldots + \boldsymbol{I}_n = 0$
  - These three laws mean we can use all time-domain circuit analysis techniques in the phasor domain!

Steps in ACSS Analysis:

1. Redraw the circuit (the phasor transform does not change the components or their connections).
2. Phasor transform all known v(t) and i(t).
3. Represent unknown voltages and currents with *V* and *I*.
4. Replace component values with impedance (Z) values.
5. Use any circuit analysis method(s) to write equations and solve them with a calculator.
6. Inverse-transform the result, which is a phasor, back to the time domain.

Chapter 8

- Instantaneous power, average power, reactive power, complex power (power triangle)
- Power factor
- RMS values for power calculation
- Maximum average power transfer to the load (un-restricted and restricted)
- Transformer – reflected impedance, ideal transformer

Resistive, Inductive, Capacitive Circuits

- Resistors $P > 0$, $Q = 0$
  - ➢Resistors absorb real power and have no reactive power
- Inductors $P = 0$, $Q > 0$
  - ➢Inductors absorb reactive power and have no real power
- Capacitors $P = 0$, $Q < 0$
  - ➢Capacitors generate reactive power and have no real power